

The Robot-Human Continuum

Concepts, Evolution, and Applications
For Space Exploration

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Revolutionary Aerospace
Systems Concepts
For Human/Robotic Exploration
Of The Solar System

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Abstract

Human use of robots is still in its infancy. Robotic devices handle repetitive or voluminous tasks, mass data acquisition, and management in many current Earth applications. However, the unique challenges presented by space exploration render collaborations between humans and robots essential. The products of those collaborations will be novel and driven by the features of wholly new environments.

Relative degrees of integration between human and device fall along a continuum. This continuum begins with exclusively robotic missions of the present type (and those envisioned in the near future), and progresses to the point where distinctions between the organic and non-organic components are blurred. Stages in the development of interorganism collaboration in Earth's biosphere over evolutionary time provide conceptual parallels for such future hybrid robot-human consortia.

For space and planetary environments that are intolerable for humans or where humans present an unacceptable risk to possible biologically sensitive sites, autonomous robots or telepresence offer excellent choices. The search for life signs on Mars fits within this category. We are attempting to robotically emulate a human field scientist's modus operandi, exemplified by our *Mother Goose Mission* concept.

For human space missions or Earth applications in difficult environments, human-guided and autonomous robotic assistants are both valuable. Our proposed *Spelescope* instrument is envisioned as a first step along this path.

For environments on spatial scales radically different from humans, all of the above robotic manifestations may be applicable. For example, engineered organisms, nanomachines or hybrids of both could be used for extractive mining processes or even for establishing substitute recycling mechanisms on non-subductive planets like Mars.

Development of biological robots and increasingly instrument-enhanced humans could lead to symbioses (analogous to lichens) or even syncytia (analogous to mitochondria). Currently, pacemakers and other medical implant mechanisms can be considered primitive precursors to these. Developments in genetic modification, progress in the instrumentation of higher organisms (plants), and the tantalizing possibility of permanent internal nanomechanisms on cellular scales are critical-path technologies preparatory to organic-machine hybridization.

Epistemological consequences flow from each of these choices. For some highly advanced human-robot associations, ethical considerations will also arise. If we endow advanced robots and human-robot consortia with certain properties, they may ultimately transcend our present ability to anticipate or control their direction. Such new entities will qualify as lifeforms in their own right. Their collective behavior will qualify as a classical evolving system.

Why Do We Need & Want Robots?

- ✂ Numerous or repetitive tasks
- ✂ Mass data acquisition & management
- ✂ Nasty environments
- ✂ Tiny environments
- ✂ Huge environments
- ✂ Sensitive environments
- ✂ Pets
- ✂ Self extensions

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Robot-human Continuum

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Tool



Self

Human Robotic Consortia

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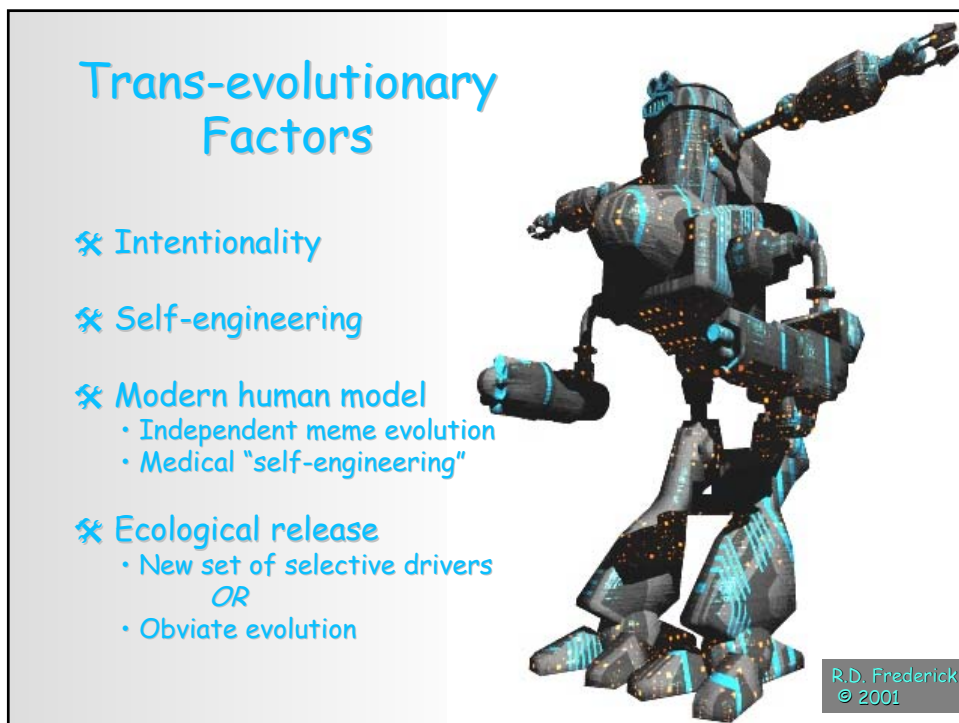
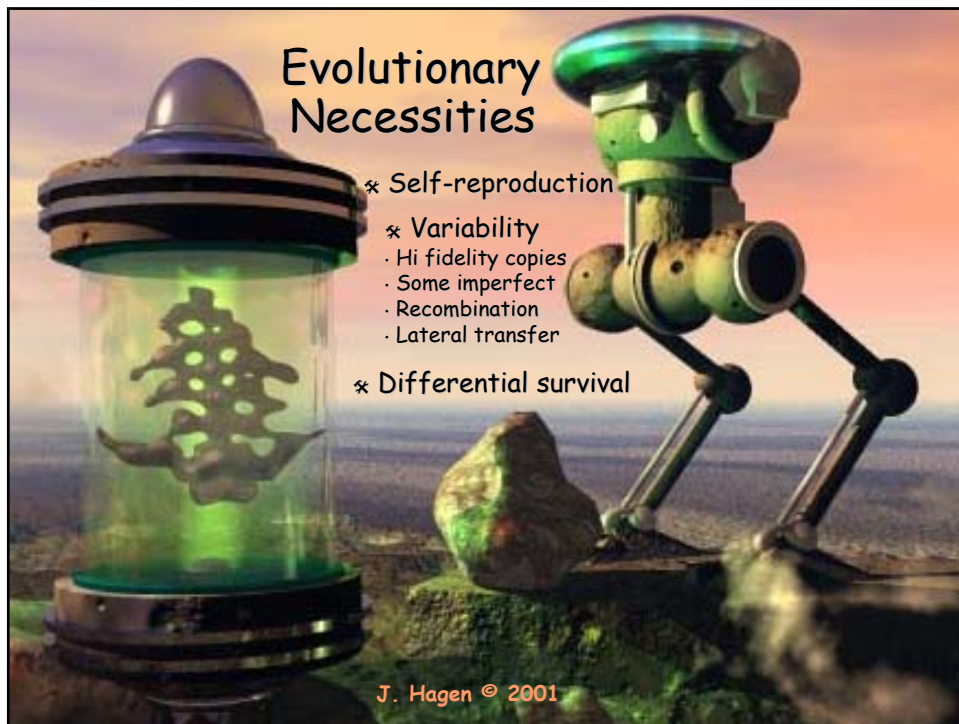
- ✂ Robotic missions
- ✂ Human-guided robots
- ✂ Autonomous assistants
- ✂ Telepresent missions
- ✂ Biological robots
- ✂ Instrumented humans
- ✂ Cyberorganic syncytia




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Biological Paradigms

- ✂ Parasitism
- ✂ Commensalism
- ✂ Symbiosis
- ✂ Endosymbiosis
- ✂ Organellization
- ✂ Syncytia





Techniques

- * Genetic manipulation
- * Genetic transformation
- * Designer biomolecules
- * Bionics
- * Robotic engineering
- * Nanoengineering

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Human Emulation in Robotic Missions

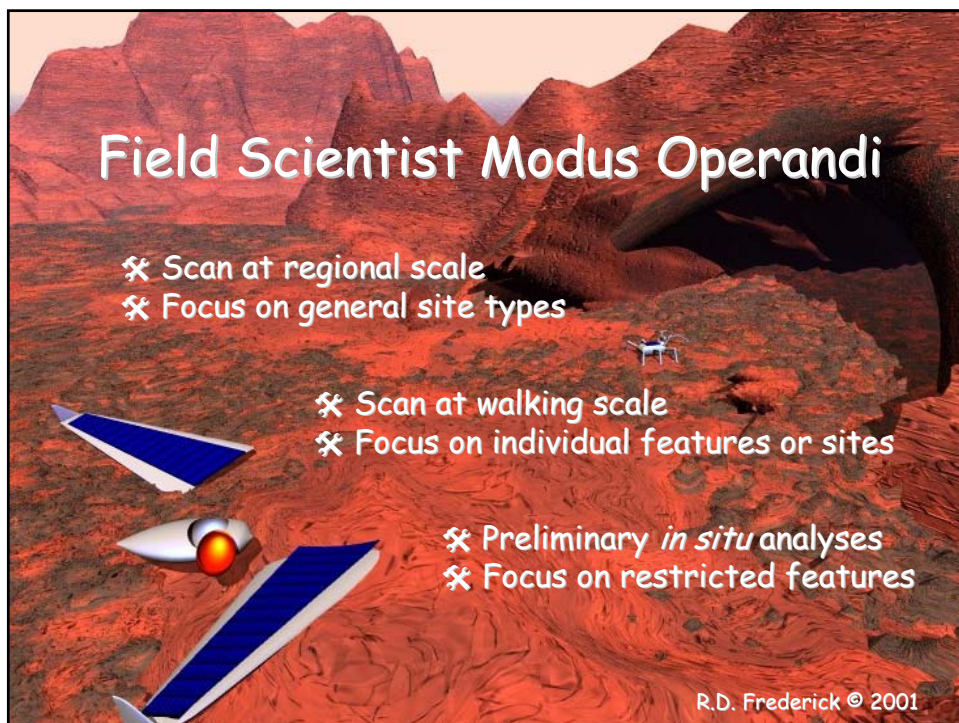
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The Field Scientist in the Wild



The Field Scientist In A Can





Field Scientist Modus Operandi

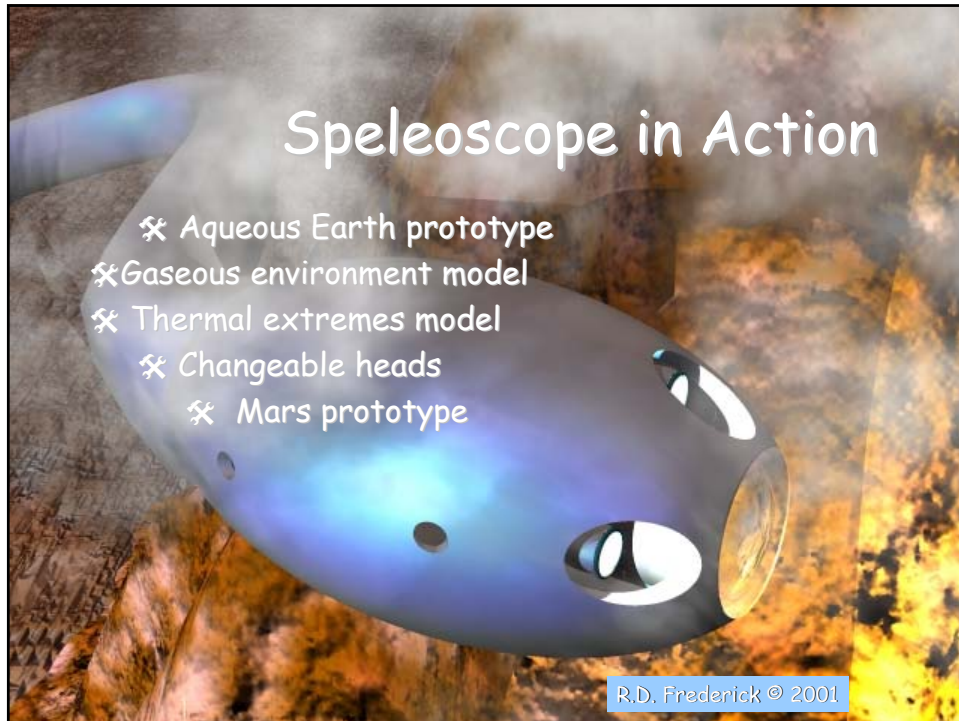
- * Mother conducts in depth, *in situ* studies
- * Deploys auxilliary microunits
- * Microunits conduct in depth, *in situ* studies
- * Return data & selected samples to field lab, orbital craft, or Earth
- * Do it *ALL* over again!

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Human-guided Robots

- * Semi-autonomous
- * Earth extremophile applications
- * Sterilizable

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Planetary Protection and Human Protection

- * Possible biological sites
- * Dirty/clean model
- * Contamination zone model
- * Aseptic reconnaissance
- * Preliminary assessments
- * Long-term monitoring
- * Intermediates in chain of asepsis
- * Class IV+ containment

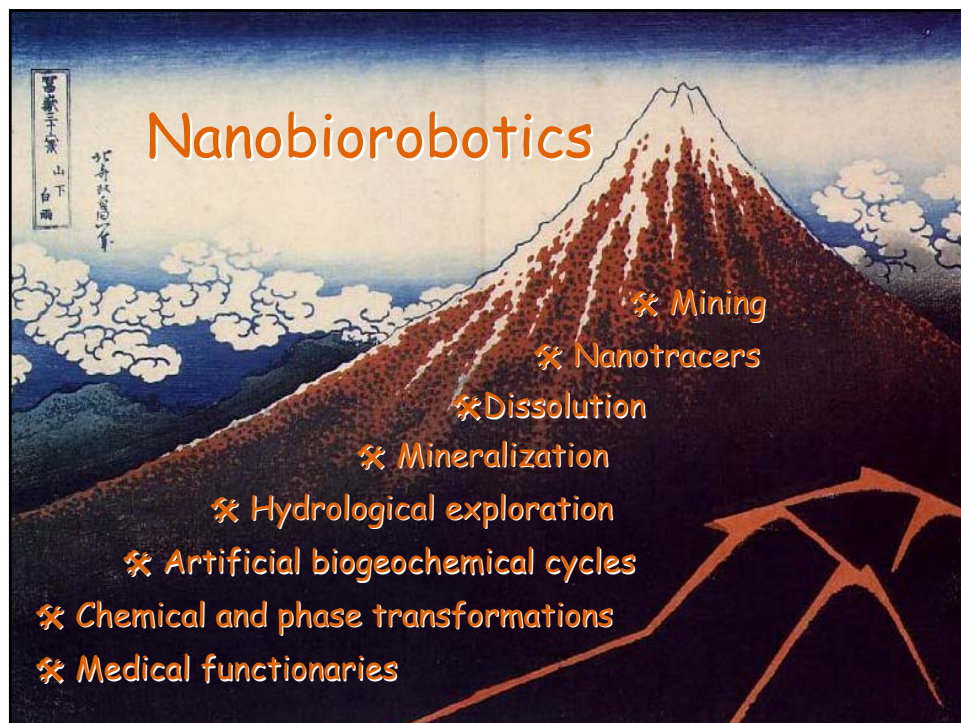
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Bugbots

- * Sub-human scale exploration
- * Microscale analyses
- * Self-deploying networks
- * Distributive intelligence

Dubowskoids
Inc.

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Telepresent Missions

- ✧ Planetary protection
- ✧ Hostile environments
- ✧ Tiny environments
- ✧ Huge environments
- ✧ Alternative senses
- ✧ First step towards neural integration

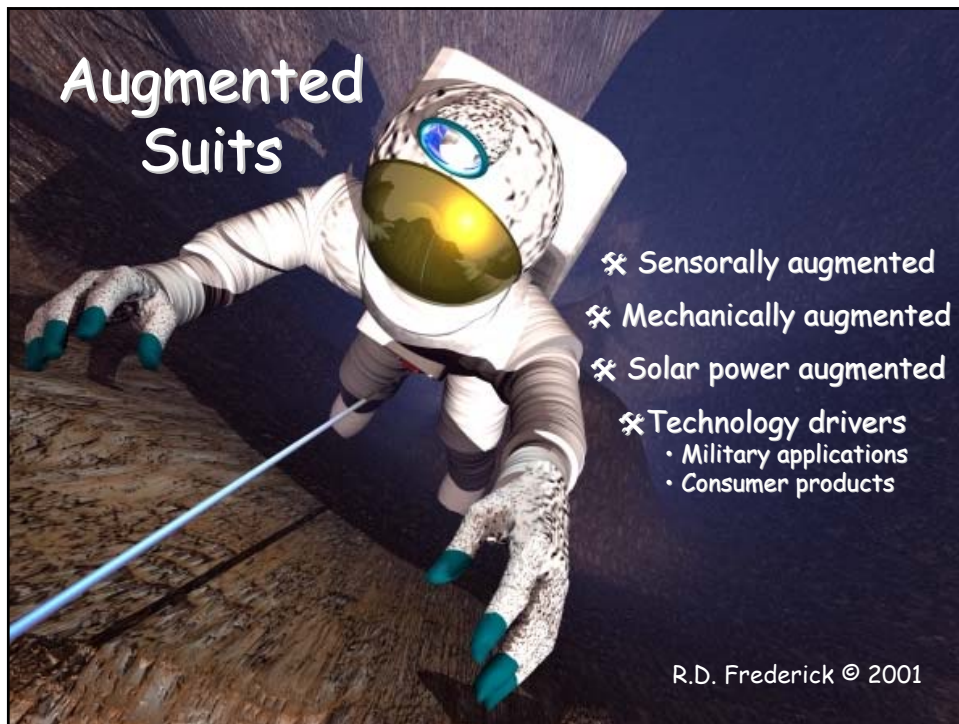
Biological Robots

- ✧ Protein-based memories
- ✧ Chemical switches
- ✧ Molecular self-assembly
- ✧ Bacteriorhodopsin retinas
- ✧ Metallised DNA nanowires
- ✧ Enzyme/thin film hybrids
- ✧ Neuron-like associative processors



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Bionic Humans

- ✧ Neurally integrated components
- ✧ Regenerating "skins"
- ✧ Photosynthetic?
- ✧ Symbiotic?



Epistemology

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- ✂ Sensation
 - ✂ Experience
 - ✂ Falsifiability
 - ✂ Veracity
 - ✂ Truth

- ✂ How do we know what we think we know?
- ✂ How does human/robotic collaboration complicate this issue?

Ethics

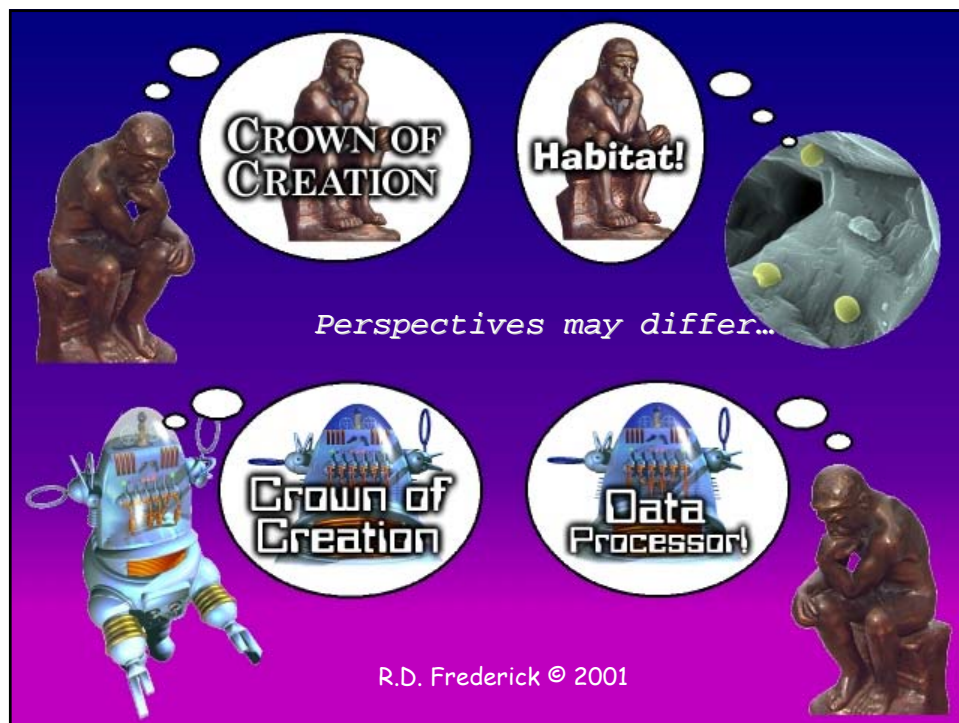
✧ Organicness

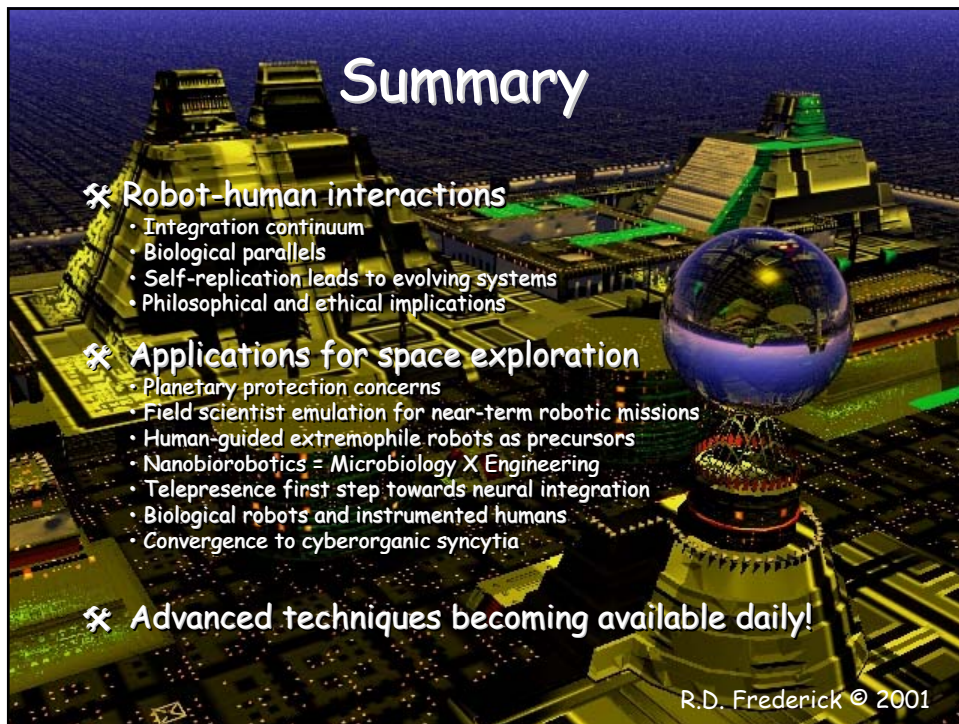
✧ Sensateness


✧ Self awareness

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✧ Beinghood







Collaborators:

Equinox Interscience, Inc. (<http://eisci.com/>)
SLIME TEAM (Subsurface Life in Microbial environments, <http://www.i-i.com/~diana/slime/>)

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